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Is Renewable Heat Incentive the future?

Siti Hawa Abu-Bakar [a,b,*], Firdaus Muhammad-Sukki [a,c], Roberto Ramirez-Iniguez [a], Tapas Kumar Mallick [d], Campbell McLennan [e], Abu Bakar Munir [f], Siti Hajar Mohd Yasin [g], Ruzairi Abdul Rahim [h]

[a] School of Engineering & Built Environment, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow, G4 0BA Scotland, United Kingdom
[b] Universiti Kuala Lumpur British Malaysian Institute, Batu 8, Jalan Sungai Pusu, 53100 Gombak, Selangor, Malaysia
[c] Faculty of Engineering, Multimedia University, Persiaran Multimedia, 63100 Cyberjaya, Selangor, Malaysia
[d] College of Engineering, Mathematics and Physical Sciences, University of Exeter, Penryn, Cornwall TR10 9EZ, United Kingdom
[e] AES Ltd, AES Building, Lea Road, Forres, IV36 1AU Scotland, United Kingdom
[f] Faculty of Law, University of Malaya, 50603 Kuala Lumpur, Malaysia
[g] Faculty of Law, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia
[h] Faculty of Electrical Engineering, Universiti Teknologi Malaysia, UTM Skudai, 81300 Johor, Malaysia

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ABSTRACT

This paper focuses on the renewable heat incentive (RHI) scheme in the United Kingdom (UK); and in particular, on its implications in relation to solar thermal systems (STSs). First, a short review on the UK's energy demand is provided. Then, an overview of the past and present activities related to STS installations is discussed, covering regulation, policies and programmes, research and development expenditures and implementations. A financial analysis is presented afterwards, analysing the RHI scheme, in terms of total profit, payback period and average annual return on investment. This is based on installations of different sizes and at various levels of solar insolation. The analysis also presents the reduction of carbon dioxide emissions that could be achieved by installing an STS. From the financial analysis it is found that the RHI scheme could generate a good total profit, a high average annual return on the investment and an 'acceptable' payback period, depending on locations. As a result, it could increase the penetration of solar thermal systems in the UK. Significant reductions of carbon dioxide emission can also be achieved by installing an STS on a building.

Contents

* Corresponding author at: School of Engineering & Built Environment, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow, G4 0BA Scotland, United Kingdom. Tel.: +44 141 273 1482; fax: +44 141 331 3690.
E-mail addresses: sitihawa.abubakar@gcu.ac.uk, hawa012@gmail.com (S.H. Abu-Bakar), firdaus.muhammadsukki@gcu.ac.uk (F. Muhammad-Sukki).

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1. Introduction

Renewable energy has grown significantly in the past few years. A report by the Renewable Energy Policy Network for the 21st Century (REN21) [1] indicates that presently, about 16.7% of the world's energy consumption is from renewable sources and the rest from fossil fuels and nuclear. Solar energy is one of the forms of renewable energy that has great potential. In 2010, Abbot [2] estimated that solar energy could produce 85,000 TW per year, enough to satisfy the world's energy requirement of 15 TW. The two main applications of solar energy are for electricity generation (via solar photovoltaic (PV) systems and concentrating solar thermal power (CSP)) and for solar heating and cooling (SHC) applications [3].

One of the technologies for SHC applications is the solar thermal system (STS).[1] An STS utilises the heat from the sun to increase the temperature of water. A typical STS consists of four main components (see Fig. 1) [4]: (i) a solar collector which is used to collect solar energy; (ii) a storage tank for storing the solar-heated water; (iii) a supporting stand to mount the solar collector, and (iv) connecting pipes and devices such as the boiler, drain valve, pump and sensors. When the demand cannot be met by a solar collector, the system is usually in need of an auxiliary means of heating the water, i.e. it needs to use a boiler. The three most common collectors for STS are unglazed, flat plate and evacuated tube [5].

The International Energy Agency (IEA) has reported that in early 2011, the solar thermal market has reached 245 GW_{th} of installed capacity and generated 204 TWh [6]. In terms of total capacity and energy production, solar thermal is placed second only to wind amongst the renewables [6], as illustrated in Fig. 2. In terms of annual growth rate in 2011, solar thermal system was placed third (27%) behind solar PV (74%) and CSP (35%) [1]. The vast majority of the capacity was installed in China (117.6 GW_{th}) and Europe (36.0 GW_{th}), corresponds to 78.5% of the total installation worldwide [6].

The United Kingdom (UK) is one of the countries that have been focusing in developing and installing STS. The country is located in the Western Europe and consists of four states—England, Wales, Scotland and Northern Ireland covering a total area of 243,610 km^2 [7]. It has a total population of 63 million people [7], living in approximately 26.4 million households [8].

From 1970 until 2011, the total energy consumption in the UK varies between 1579 and 1871 TWh per year mainly from petroleum, gas, electricity and solid fuel [9]. Although the energy consumption does not differ much, significant changes can be seen in terms of total expenditure on energy, as illustrated in Fig. 3. The UK spent about £5 billion in 1970, but the amount increased by 27 fold in 2011, totalling £134 billion [9] mainly due to the increase in the fossil fuel price. In 2011, the UK consumed 1610 TWh of energy, primarily in four major sectors; transport (30%), domestic (30%), industry (23%) and services (17%) [9]. A detailed breakdown of the energy usage for each sector (excluding the transport sector) indicated that heat is the major contributor to the energy usage, about 81%, 54% and 65% for the domestic, service and industry sectors respectively [9]. Table 1 shows the breakdown of energy consumption by end users (excluding the transport sector) in 1990, 2000, 2010 and 2011.

It is projected that by 2030, the total population will increase to 69.9 million people and the total number of households will increase by 21% totalling to about 32.1 million [10]. The increase in population could result in an increase in the energy requirement in the country. This, plus other factors such as fossil fuel dependency, energy security and energy cost prompted the UK Government to introduce a number of measures to elevate the usage of renewable energy in the country. STS is one of the possible solutions in providing heat to buildings.

The government has expressed its commitment to increase the renewable energy penetration in the country, which includes solar energy. The UK receives a moderate amount of sunlight, with an insolation of between 800 and 1300 kWh/m^2 per year [11] depending on location, with an average of around 1000 kWh/m^2 [12]. Fig. 4 shows the average yearly solar insolation in the UK.

Section 2 presents an overview of past and current regulations, policies and programmes related to STSs. Section 3 discusses the research and developments spending while national implementation of STS is evaluated in Section 4. Section 5 presents a financial analysis in relation to the Renewable Heat Incentive and its impact on domestic and non-domestic consumers in the UK. In Section 6, the reduction in carbon dioxide emissions by installing STSs is deduced. Conclusions are presented at the end of the paper.

2. National regulations, policies and programmes

Despite the moderate levels of insolation at northern latitudes, the UK government recognises the potential of solar energy. To ensure a sufficient penetration amongst its citizens, the government has introduced a number of policies. The impact of these policies has been discussed in a number of research papers [14–16]. To date, there are about 67 different energy policies which arise both from the European Union (EU) directive and from the country's national initiatives [17]. These policies are designed to address the energy and climate change agenda as a whole. All the information on energy policies is reported to the European Commission (EC) and the qualitative database of measures for each EU country can be accessed in MURE (Mesures d'Utilization Rationelle de l'Energie), an online database created from an EC-funded project [17]. As this paper focuses on the STS, only the major policies which relate to STS installation are discussed.

[1] For this paper, a solar thermal system is defined as solar hot water and heating system.

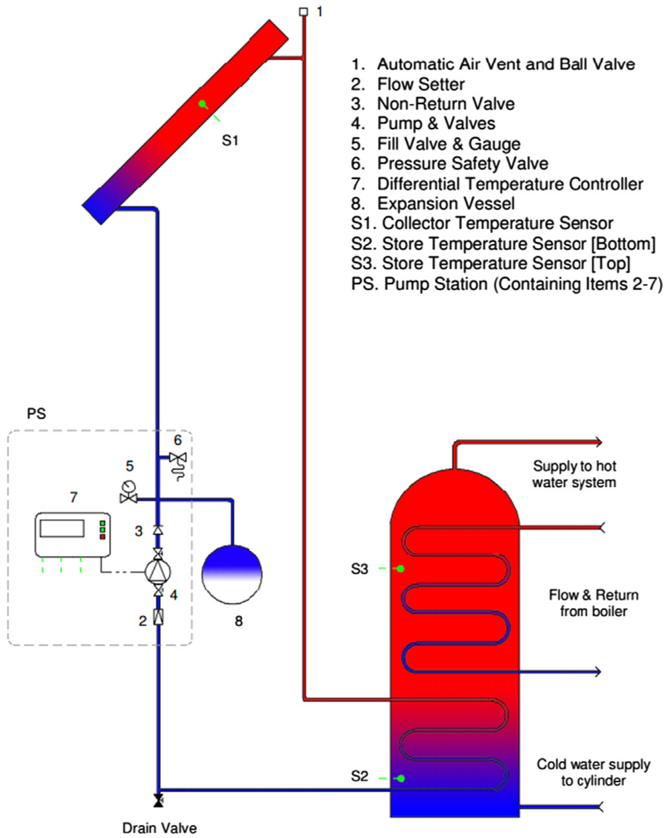


Fig. 1. A schematic diagram of a solar thermal system [4].

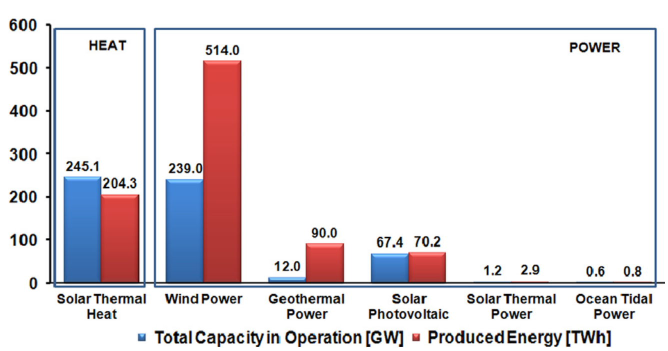


Fig. 2. Total capacity in operation [GW_{el}], [GW_{th}] and annual energy generated [TWh_{el}], [TWh_{th}] in early 2011. Adapted from [6].

Table 2 summarises the regulations, policies and programmes related to the STS in the UK.

2.1. The Energy Saving Trust (1992)

The Energy Saving Trust (EST) was initiated in 1992 by the government to ensure that Britain achieves the CO_2 reduction targets agreed at the Rio and Kyoto summits on climate change [17]. There are three parts of the EST [18]: (i) Energy Saving Trust Enterprise which helps businesses and organisations develop robust modelling and design successful future schemes; (ii) Energy Saving Trust Ltd—a wholly owned trading subsidiary of EST that manage and deliver large-scale projects and government funded programmes; and (iii) Energy Saving Trust Foundation which provides impartial, accurate and authoritative advice on how to reduce carbon emissions and the use of water more sustainably, as well as to assist people to save money on energy bills.

The EST has been involved in a number of renewable energy initiatives. Specifically for STS, the latest work by EST was to perform and evaluate the largest field trial of STSs installed in various loctions in the UK and the Republic of Ireland from 2009 until 2011 [5]. A total of 88 sites have been identified and installed with 54 flat plate systems and 34 evacuated tube systems. The field trial cost was approximately £700,000 [19]. From the field trial, the EST found that [5]: (i) a properly installed STS could provide roughly 60% of a household's hot water, producing around 1500 kWh of energy annually; (ii) the householders involved in the trials are happy with their STSs, with 84% of them rating the STSs as 'fairly satisfied' or 'very satisfied'; (iii) the installation of a STS could save a household between £30 and over £100 on energy bills depending on whether the STS is replacing the gas or the electric immersion heating, and (iv) in terms of CO_2 emissions, the savings range from 50 to 500 kg of CO_2 per year depending on whether the STS is replacing the gas or the electric immersion heating.

According to the recent EST Annual Report [20], the EST programmes managed to reduce the overall carbon foot print by 8% in 2010/2011 when compared to 2009/2010, totalling 377.67 tonnes of CO_2. The report also indicates that the funding for the 2010/2011 totals £123 million. However, starting from April 2012, the government ceased the funding for EST, mainly due to the introduction of the Green Deal [17]. The EST has started to become a social enterprise to fund its own programmes [17].

2.2. Energy Efficiency Commitment (2002)

The Energy Efficiency Commitment (EEC) was introduced in 2002, obliging the energy suppliers to achieve specific target of energy savings in their consumers' households, i.e. by promoting and implementing higher energy efficiency measures, such as insulation, heating, lighting and appliances [14,15,21]. The EEC supported two UK Government programmes: (i) the Climate Change Programme—by reducing the greenhouse gas emissions, and (ii) the Fuel Poverty Strategy—by ensuring that 50% of the target must be met in relation to certain low-income consumers [22]. The first phase operated from 2002 to 2005 and the second phase spanned from 2005 to 2008, aiming to achieve energy savings of 62 TWh and 130 TWh respectively [15]. Interestingly, both targets were exceeded, with the first phase achieving 86.8 TWh [21] while the second phase achieving 187 TWh [22]. The EEC ceased in 2008 and was rebranded as the Carbon Emissions Reduction Target (CERT) [22].

2.3. Energy Act (2004)

This Act is one of the first crucial steps that help towards greater STSs penetration in the UK. One of the key aspects in this Energy Act 2004 is to make provisions for the development, regulation and encouragement of the use of renewable energy sources in the country as mentioned specifically in Part 2 of the Act [23]. Section 82 provides that the Secretary of the State must prepare a strategy for the promotion of microgeneration within 18 months after the commencement of the Act. Microgeneration is defined as 'the small scale production of heat and/or electricity from a low carbon source' [14,24], including the STS. The Act emphasises that the strategy for microgeneration must be capable of cutting greenhouse gas emissions, reducing the number of people living in fuel poverty and enhancing the availability of electricity and heat for consumers in the UK [23].

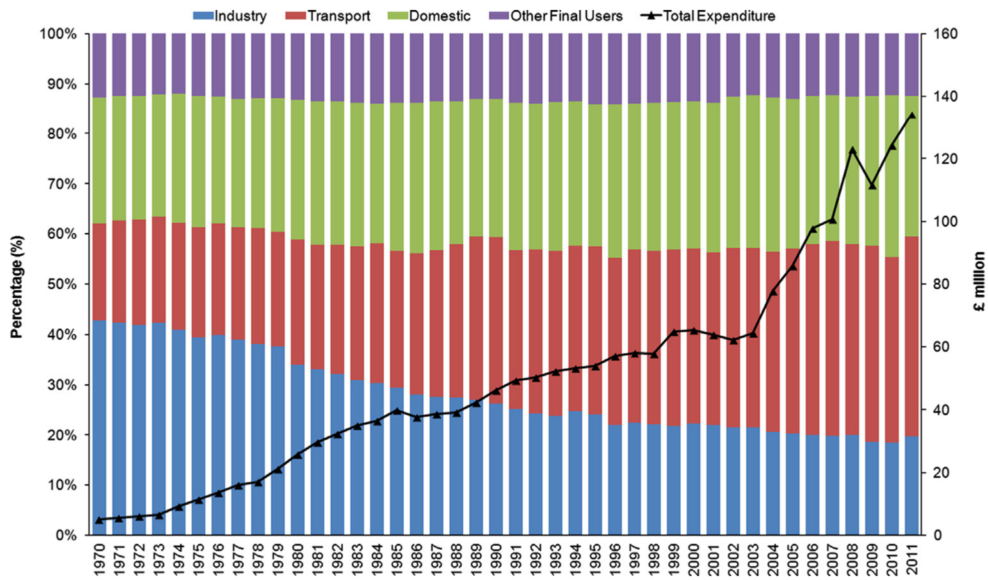


Fig. 3. Breakdown of energy consumption in the UK according to sectors and the total expenditure on energy (1970–2011). Adapted from [9].

2.4. *Climate Change and Sustainable Energy Act (2006)*

The purpose of the Climate Change and Sustainable Energy Act 2006 is to enhance the UK's contribution to combating climate change [24]. Among the important provisions in the Act are to [25]: (i) put greater emphasis on microgeneration—by requiring the Secretary of State to designate one or more national microgeneration targets between 1 November 2008 and 21 March 2009; (ii) promote the use of heat produced from renewable sources; (iii) encourage community energy project, and (iv) reduce the greenhouse gas emissions.

2.5. *Microgeneration Strategy (2006)*

Microgeneration Strategy was developed after the introduction of the Climate Change and Sustainable Energy Act 2006. The objective of this strategy is 'to create conditions under which microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, for the community and for small businesses' [24]. The technologies that fall into the microgeneration technology include micro-wind, micro-hydro, ground source heat pumps, biomass boilers, STS, solar PV, micro-combined heat and power (CHP) and fuel cells [23,24]. This strategy outlines the potential for microgeneration in the UK in terms of tackling the climate change, ensuring reliable energy supplies and addressing fuel poverty. It is projected that microgeneration technologies could generate about 30% to 40% of the UK's electricity needs and help to reduce annual household carbon emissions by 15% [24]. However, there are some obstacles in accelerating the microgeneration installations. They are [24]: (i) high cost of installation; (ii) lack of awareness amongst the people; (iii) technology constrains such as metering and connection to the distribution network, and (iv) lack of regulatory measures for planning permission and building regulations. To address these issues, some actions are proposed [24]: (i) introducing grants to finance the capital cost of installation such as the Low carbon Building Programme and the EEC; (ii) engaging with various groups including the EST, trade associations and local authorities in providing awareness and advice to households and communities; (iii) collaborating and partnership with the energy supply companies, distribution network operators and Office of the Gas and Electricity Markets (OFGEM) to ensure that network and market systems are able to deal with increasing numbers of microgenerators exporting electricity into the grid, and (iv) to amend existing regulatory measures to ease the installation of microgeneration on new and existing buildings.

2.6. *Low Carbon Building Programme (2006)*

The Low Carbon Building Programme (LCBP) was initiated to support the Microgeneration Strategy, with a total budget of £137 million from the government [26]. This grant spanned until 2011 providing funds to various groups (e.g. householders, schools, communities etc.) to acquire and install microgeneration technologies. The LCBP was divided into two phases; Phase 1 focussed on the householders, community projects and some larger major projects and was managed by the EST while Phase 2 focussed on non-domestic not-for-profit installations and was managed by the Building Research Establishment (BRE) [26]. At the end of the programme, there were 19,212 installations recorded [26]. The STS covered 44.8% of the total installations (about 8611), amounting to approximately £15 million of the grant value [26]. More than 90% of the STS installations were carried out in domestic buildings [26]. Fig. 5 shows the breakdown of the number of installations based on technology for the LCBP.

2.7. *Carbon Emission Reduction Target (2008)*

The Carbon Emission Reduction Target (CERT) was launched to replace the EEC in 2008. It carries the same framework as the EEC, but in addition, it includes the microgeneration and behavioural measures within the scheme [27]. The CERT has targeted a total lifetime savings of 293 million tonne of CO_2 by 2012 [27]. According to the report by OFGEM [28], as of September 2012, 87% of the target has been achieved, where 1% of the target is contributed by microgeneration technology and CHP. To date, a total of 3091 m^2 of STS has been installed in the UK under this scheme [28].

2.8. *Climate Change Act (2008)*

The Climate Change Act received Royal Assent in November 2008 and has demonstrated the UK's commitment in tackling the climate change agenda. The Act has set a legally binding target of a minimum of 80% cut in greenhouse gas emissions by 2050, to be achieved through action in the UK and abroad [29]. A medium-term

Table 1
The non-transport energy consumption (in TWh) by end use in 1990, 2000, 2010 and 2011. Adapted from [9].

	1990[a]				2000				2010				2011			
	Domestic	Industrial	Service[b]	Total	Domestic	Industrial	Service[b]	Total	Domestic	Industrial	Service[b]	Total	Domestic	Industrial	Service[b]	Total
Space heating	275.6	44.2	114.0	433.8	333.8	39.5	130.3	502.4	382.6	43.0	93.0	518.7	272.1	41.9	84.9	400.1
Water	117.5	0.0	19.8	137.2	124.4	0.0	22.1	146.5	81.4	0.0	17.4	100.0	81.4	0.0	16.3	97.7
Cooking/Catering	17.4	0.0	20.9	38.4	15.1	0.0	24.4	39.5	12.8	0.0	20.9	33.7	12.8	0.0	19.8	32.6
Lighting/Appliances	64.0	4.7	30.2	98.9	70.9	3.5	34.9	109.3	86.1	3.5	39.5	127.9	84.9	2.3	39.5	126.8
Process use	0.0	252.4	0.0	252.4	0.0	193.1	0.0	193.1	0.0	133.7	0.0	133.7	0.0	131.4	0.0	131.4
Motors/Drivers	0.0	25.6	0.0	25.6	0.0	26.7	0.0	26.7	0.0	33.7	0.0	33.7	0.0	33.7	0.0	33.7
Drying/Separation	0.0	37.2	0.0	37.2	0.0	38.4	0.0	38.4	0.0	32.6	0.0	32.6	0.0	31.4	0.0	31.4
Other[c] non-transport	0.0	86.1	22.1	108.2	0.0	110.5	25.6	136.1	0.0	75.6	29.1	104.7	0.0	74.4	29.1	103.5
Total	474.5	450.1	208.2	1131.6	545.4	411.7	236.1	1192.1	564.1	322.2	201.2	1086.2	451.2	315.2	188.4	956.0

[a] In 2000, 2010 and 2011, all of heat sold is classed under 'space heating'. However, for 1990, as heat sold is not available as a separate figure, this consumption is spread out across all of the end uses.
[b] Excludes all energy consumption in the agriculture sub-sector.
[c] Includes construction and unclassified energy use in the Industrial column but excludes energy used in the manufacture of coke, refined petroleum products and nuclear fuel (SIC2003 class 23; SIC2007 class 19).

target of at least 34% reduction in emissions has been set for 2020 [30]. Both targets are set against the 1990 baseline.

To achieve these targets, Section 4 outlines the principle of five-year carbon-budgets [29]. In 2009, the government has produced three carbon-budgets that cover 2008–2012, 2013–2017, and 2018–2022 [15]. To facilitate the government, a new independent, expert body known as the Committee on Climate Change (CCC) was created by the Act [29]. This body advises the government on the level of carbon budgets and on where cost-effective savings can be made, as well as submitting annual reports to the Parliament on the progress towards the targets and budgets [15,30]. To ensure transparency and accountability, the government is responsible to respond to the report on an annual basis [30].

2.9. Energy Act (2008)

The Energy Act 2008 is a crucial milestone for the STS development in the country. Section 100 requires the Secretary of State to create a scheme to facilitate and encourage heat generated from renewable sources, as well as to administer and to finance the scheme [31]. This Act makes provisions on the payments for the renewable generation of heat known as the Renewable Heat Incentives [31].

2.10. The UK National Renewable Energy Action Plan (2010)

Article 4 of the European Renewable Energy Directive (2009/28/EC) requires all Member States to submit a National Renewable Energy Action Plan (NREAP) [32]. To fulfil this obligation, the government introduced the NREAP in 2010. It provides all the trajectory and measures that will ensure the target of 15% of energy consumption in 2020 is supplied by renewable sources [32]. According to the 'lead scenario', the NREAP document projected that by 2020, renewable energy will provide 239 TWh of gross final consumption, where 395 GWh will come from STS [33].

2.11. Renewable Heat Premium Payment (2011)

The Renewable Heat Premium Payment (RHPP) scheme, administered by the EST, is being implemented in two phases [34,35]. The first stage started on 1 August 2011 and ran until 30 April 2012 with a fund of £15 million [34]. There are two sectors which benefitted from the first phase; domestic and social housing sectors [34,35]. For the domestic sector, this short-term scheme is a one-off payment to help with the capital payment for installing the desired heat technology, ranging from £300 to £1250 (as illustrated in Table 3) [35]. Specifically for STS, any household could benefit from a £300 voucher for installing the system. There are a number of conditions that need to be fulfilled to apply for this scheme. These include [34,35]:

(i) The scheme is only available for organisations and communities in England, Scotland and Wales.
(ii) For household applicant, the house has to be the main house of the applicant. Tenants must purchase the system themselves and have permission from their landlord to install it.
(iii) The applicant needs to confirm that the property has satisfied a minimum insulation requirement, i.e. a loft insulation to 250 mm and cavity wall insulation (where practical).
(iv) The renewable heat product must be listed under the Microgeneration Certification Scheme (MCS), and be installed by someone registered under the MCS scheme, or equivalent.
(v) The applicant agrees to have an extra metre attached (free of charge) to monitor and learn about how heating systems are

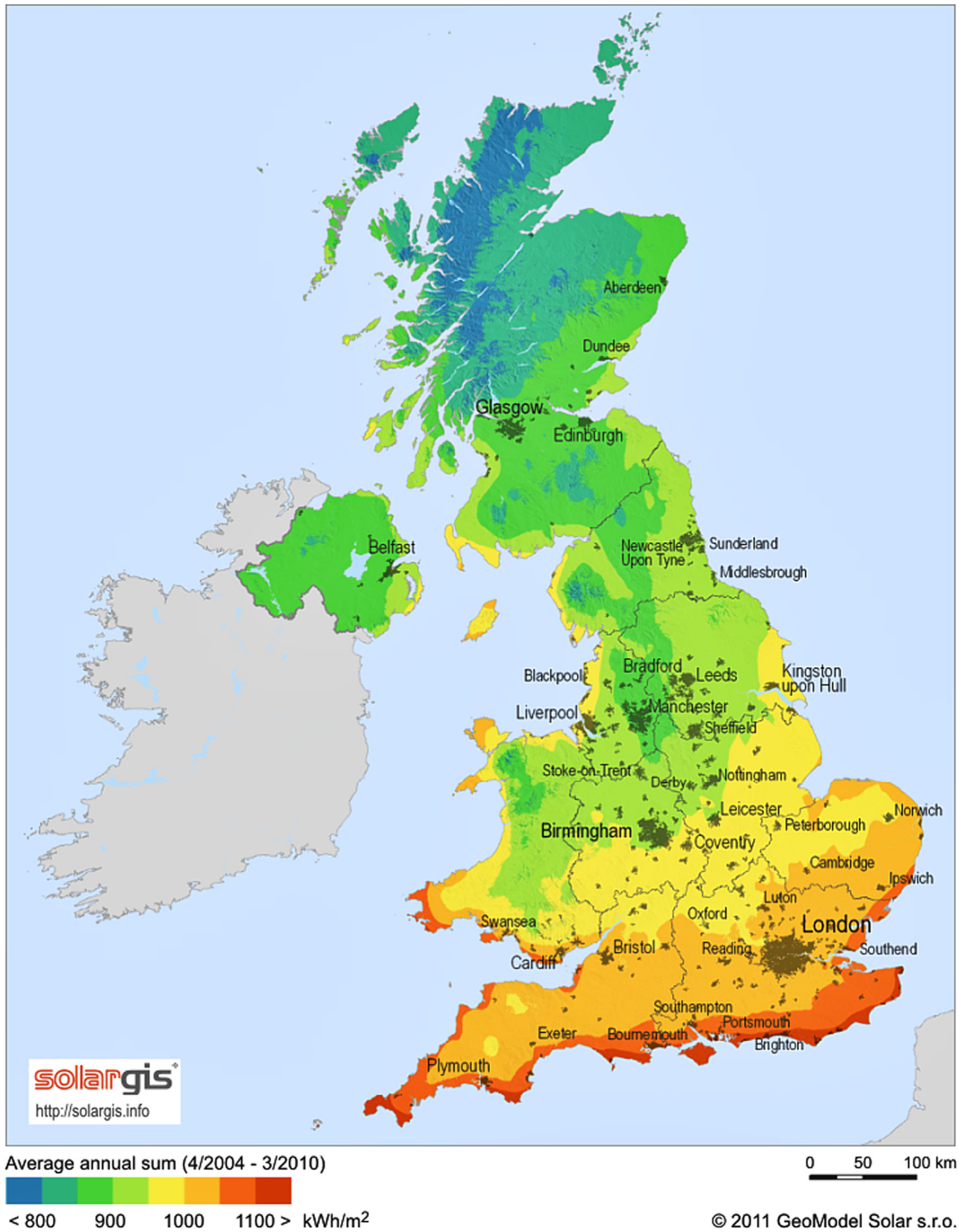


Fig. 4. Average yearly solar insolation for the UK [13].

used in practice in various different circumstances and types of home.

To speed up the deployment of renewable heating technologies in the social housing sector, the Department of Energy and Climate Change (DECC) launched a bidding competition in August 2011 known as Phase 1 of the Social Landlord Competition [34]. Any Registered Providers of social housing were invited to bid for grants for projects to install renewable heating technologies. The panels from the EST and DECC will then assess the projects according to specific criteria i.e. value for money, total energy savings secured, deliverability and delivery innovation and total fuel displaced [36]. A cap of a maximum of €200,000 sterling equivalence is introduced, which is aligned to the European Commission's rules for state aid funding to fund up to €200,000 [36]. Any project related to the installation of an STS for the Social Landlord Competition could gain a fund of between £300 and £2000 [36].

At the end of Phase 1, a total of 7253 vouchers have been issued by the EST for the domestic sector, with a value of approximately £5.5 million [35]. From 5369 vouchers that have been redeemed, 33% of them are for STSs. Fig. 6 shows the total number of RHPP vouchers redeemed in various locations in the UK at the end of Phase 1 [35]. As for the social housing sectors, 37 social landlords secured funding from the competition, amounting to a total value

Table 2
Summary of measures that relate to the STS.

Item	Regulatory	Policies	Programme	Financial incentive
Energy Saving Trust (1992-to date)			/	/
Energy Efficiency Commitment (2002–2008)				/
Energy Act (2004)	/			
Climate Change and Sustainable Energy Act (2006)	/			
Microgeneration Strategy (2006)		/		
Low Carbon Building Programme (2006–2011)				/
Carbon Emission Reduction Target (2008–2012)				/
Climate Change Act (2008)	/			
Energy Act (2008)	/			
The UK National Renewable Energy Action Plan (2010)		/		
Renewable Heat Premium Payment (2011–2013)				/
Renewable Heat Incentive (2011-to date)				/
Microgeneration Strategy (2011)		/		
Energy Act (2011)	/			
Green Deal (2012)				/

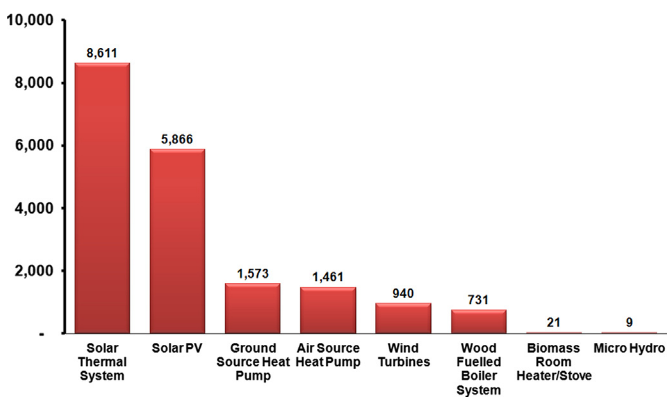


Fig. 5. Number of installations based on technology for the LCBP. Adapted from [26].

Table 3
Renewable Heat Premium Payment (RHPP) scheme [35].

Technology	Voucher value (£)
Solar thermal system	300
Air-to-water heat pump	850
Ground-source or water-source heat pump	1250
Biomass boiler	950

of £3.7 million [34]. The grant was used to install 948 renewable heating technologies in 914 homes [36].

The second stage of the RHPP commenced on 1 May 2012 until 31 March 2013, with a total fund of £25 million [34]. For the second phase, three groups could benefit from it which are the domestic, social housing and communities [34,35]. Similar to the first phase, any householders could gain a voucher scheme with specific value as illustrated in Table 3. The pot value of the household sector totals to £7 million. The latest report by the EST indicated that a total of 1490 vouchers have been issued to the householders, amounting to approximately £1 million [35]. Out of this figure, 42% is contributed by the STS. The vast majority of the vouchers were redeemed in England (78%) followed by Scotland (14%) and Wales (8%) [35].

As for the social housing sector, the scheme (known as Phase 2 of the Social Landlord Competition) was available from 28 May 2012 and closed on 4 July 2012 with a pot value of £10 million [34]. Similar requirements from the previous competition were applicable, with the deadline for all projects set on the 31st March 2013. According to the EST, there are 71 projects approved for this scheme [36].

Specifically for the communities, the RHPP Community Scheme will support them in installing clusters of domestic renewable heating systems—by providing vouchers to the households in the community [34]. The application period for this scheme spanned from 24 July 2012 until 7 September 2012 with a pot value of £8 million [34]. This scheme helps to facilitate the communities (particularly the low and middle income household) to cost-effectively organise local buying groups for renewable heating systems, which will result in achieving bulk discounts as well as easier deployment for installers [35]. There is no cap to the funding amount for each project application from the community. At the moment, three renewable heat technologies are supported under this grant, which are the STS, biomass boiler and heat pump. To apply for this funding, the community will first register their interest with the EST. Once the project passes an initial assessment, it will advance to the development phase and the communities will be supported to expand their ideas into project proposal bids, where each bid will be assessed independently. To date, there are 42 projects that have progressed into the development stage under the RHPP Community Scheme [34]. All projects need to be completed by the 31 March 2013.

On the 8 August 2012, DECC launched Phase 3 of the Social Landlords competition, mainly because Phase 2 of the Social Landlord competition has generated an underspend in the budget due to its 'competitive nature' [36]. In this scheme, two competitions were introduced, each with a funding pot of approximately £2.5 million [34,36]. They were the Phase 3 competition (application ended on the 9 October 2012) and the Phase Two "Top Up" competition (application ended on 28 August 2012). In both competitions, some of the assessment criteria have been relaxed to ensure more uptake of the scheme among the social landlords [36].

2.12. *Renewable Heat Incentive (2011)*

The Renewable Heat incentive (RHI) is a financial incentive that aims at encouraging uptake of renewable heat technologies in the UK [37]. This scheme was proposed in March 2011 [38]. It is intended that the RHI will contribute to ensure that 12% of the heating will come from renewable sources by 2020 [38]. The heat technologies that could benefit from this scheme include biomass boiler, heat pump, STS and biomethane and biogas combustion [38].

Initially, the RHI only covers the non-domestic installation of renewable heat technologies—which is Phase 1 of the RHI [38]. However, the government proposed to include financial

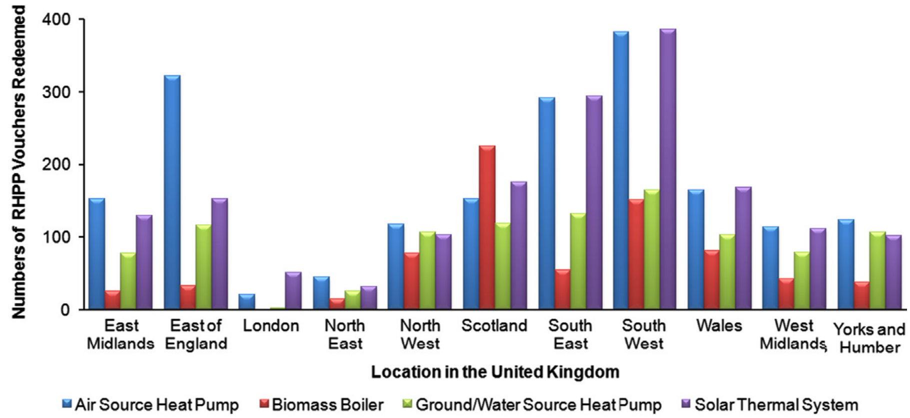


Fig. 6. Total number of RHPP vouchers redeemed in various locations in the UK (as of 30/4/2012). Adapted from [35].

payment for the deployment of these technologies for domestic usage (which is Phase 2 of the RHI) to promote more uptakes in the household sectors following a consultation in September 2012 [39]. Similar to the feed-in tariff (FiT) scheme, the RHI will guarantee a specific fixed payment per kWh of heat generated by renewable heat technology for a particular contract duration. At present, specifically for STS installed in non-domestic buildings, any installation that is less than 200 kW_{th} could gain 8.9 p per kWh for the next 20 years [38]. For domestic installations, the government proposed a rate of 17.3 p per kWh paid for a period of 7 years [39]. The RHI rate is index-linked and the yearly rate will be determined in proportion to the change in the Retail Price Index (RPI) in the previous year [38], e.g. if the RPI is 3%, the RHI rate per kWh for that year will be increased by 3%. The government projected that by 2020, Phase 1 will produce around 14,000 installations in industry and 112,000 installations in the commercial and public sectors generating approximately 57 TWh of renewable heat annually [40]. As for Phase 2, it is estimated that the domestic sector will contribute approximately 3.3 TWh annually by 2020 with a projected number of installations totalling to roughly 380,000 [39].

The application process for Phase 1 started on the 28 November 2011 and is administered by OFGEM [41]. The government allows any application for the RHI scheme for installations commissioned since 15 July 2009, before the RHI scheme was launched [38]. As of 30 September 2012, OFGEM reported that there were already 1000 applications, of which 348 have been accredited [42]. The applications are from installations carried out across industry, small businesses, supermarkets and schools. The funding for the acreditted installations is amounting to £1.2 million for a capacity of 98.45 MW [42]. The STS contributes to approximately 128 kW of the installed capacity, with a total of about 11 installations [42].

The budget for the RHI will come from the Government spending and an annual budget has been assigned for the next 4 years of the Spending Review period, as illustrated in Table 4 [43]. It is important that the forecast of the heat technology uptake is as accurate as possible, since the budgets are not flexible; any underspending could not be carried forward to the following year budget and overspending means a stop-start scheme will be in place [42]. A cost-control measure has also been proposed in case an unexpected and rapid surge occured[2], including suspending the RHI scheme to the next financial year and stop accepting new applications for that particular year [40,43].

Table 4
Budget allocation for RHI [43].

Financial year	Budget (£m)
2011/12	56
2013/14	133
2013/14	251
2014/15	424
Total	864

2.13. Microgeneration Strategy (2011)

As discussed earlier, the government has identified the importance of increasing the deployment of renewable micro-heat to meet the UK's renewable and carbon targets, hence the introduction of financial incentives, i.e. the RHPP voucher scheme and the RHI. Although the financial incentive is crucial, other non-financial barriers could hinder the progress of microgeneration in the future. The government indicated that these barriers could be tackled by the industry itself, and the Microgeneration Strategy 2011 has set out a number of actions based on the following areas [47,48]: (i) Microgeneration Certification Scheme (MCS)—by maximising the effectiveness of the MCS; (ii) Standard Assessment Procedure (SAP)—by changing the SAP to make it reflect more accurately the potential of microgeneration technologies; (iii) insurance and warranties—by helping policy makers and the industry better understand the consumer protection structure; (iv) skills and knowledge—by delivering and equipping competent workforce to meet the demands for microgeneration sector; (v) technology—by providing a 'whole system' approach to microgeneration deployment, and producing a clear guidance to the industry on the available technologies, and (vi) communications—by achieving consensus on the core information requirements on microgeneration.

2.14. Energy Act (2011)

The Energy Act 2011[49,50] improves the provision of energy efficiency measures to homes and businesses, and boosts the

[2] This is based on experience of the Feed-in Tariff (FiT) scheme where an overwhelming response for solar PV installations in 2011 caused an overspending in the FiT budget. As a result, a massive reduction in the FiT rate was introduced by the UK government starting from 1 April 2012 [44]. Detailed information about the FiT progress in the UK and the impact on consumers have been discussed for example in Refs. [45,46].

(*footnote continued*)

government's ability to enable and secure low-carbon energy supplies and fair competition in the energy markets. Chapter 1 of the Act includes provisions on Green Deal—a new financing framework which allows fixed improvements to the energy efficiency of households and non-domestic properties.

Chapter 4 enables the Secretary of State to create a new Energy Company Obligation (ECO) that will replace the existing obligations to reduce carbon emissions (i.e. the CERT and Community Energy Saving Programme (CESP)), which ends at the end of 2012. Similar to CERT, the ECO will be targeting appropriate measures to address the energy efficiency in the household sector. The ECO will work closely with the Green Deal.

There are also provisions introducing the RHI in Northern Ireland provided for in Sections 113 and 114, which will benefit the people in Northern Ireland in installing STSs.

2.15. Green Deal (2012)

Green Deal is an innovative financing mechanism that allows people to pay for energy-efficiency improvements through savings on their energy bills [51,52]. Both the domestic and non-domestic sectors could benefit from this scheme. There are four steps in applying for the scheme [51,52]: (i) assessment—conducted by a Green Deal Advisor or Assessor, (ii) finance—provided by the Green Deal Provider, (iii) installation—carried out by a Green Deal Installer, and (iv) repayment—by paying back the cost of the improvements over time through the electricity bill, where the electricity supplier will pass the payments on to the Green Deal Provider. The Green Deal received a budget of £200 million to fund 45 measures for improving the building's energy efficiency, and one of them is by installing an STS in the building. Further details on the scheme will be available in early 2013.

3. Research and development expenditure

This section provides an overview of the UK's research and development (R&D) expenditure in relation to the STS. A detailed discussion about the R&D activities related to STSs is beyond the scope of this paper. The UK government has spent a significant amount of money in R&D activities. Between 2000 and 2011, the R&D activities in the UK consumed on average £10 billion annually [53]. The fund is allocated in five major R&D groups; research councils, higher education funding councils, civil departments, ministry of defence, and funding contribution to European Union R&D activities. Around 1% of the funding was used to fund R&D activities related to energy [53].

It is not possible to identify the exact amount being spent specifically for STSs. However, the International Energy Agency (IEA) has produced an initiative to monitor all the expenditures of R&D activities for all countries, and this data is recorded in the IEA database [54]. Fig. 7 shows the UK's annual R&D spending for solar energy. Nevertheless, some data is not available in the database. There are four categories under the solar energy R&D activities [3]: (i) solar heating and cooling (SHC); (ii) solar PV; (iii) solar thermal power and high temperature applications, and (iv) unallocated solar energy i.e. research that could not be allocated into the first three groups. The STS falls into the first group. From the IEA data, it was indicated that the UK spent between £18,000 and £8.8 million a year for SHC, averaging at £1.4 million annually [54]. The R&D activities focus on improving the current technology, such as developing high efficiency solar collectors and building an intelligent control systems of the energy flows [3].

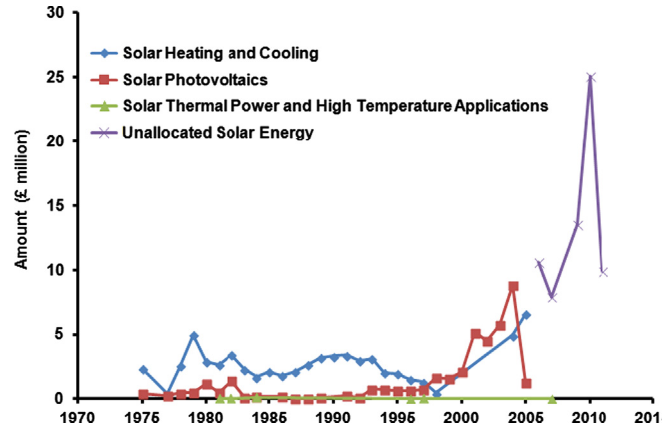


Fig. 7. Total R&D expenditure related to solar energy in the UK (1975–2011). Adapted from [54].

4. Installation of STSs in the UK

The installation of STSs in the UK has been showing an upward trend. According to the report by the European Solar Thermal Industry Federation (ESTIF), the total capacity installed in the UK grew from 74 MW_{th} in 2001 to about 460 MW_{th} in 2011 [55]. After the introduction of the Microgeneration Strategy and LCBP in 2006, the installations of STS in 2006 and 2007 increased to double the amount installed in 2005, at 38 MW_{th} annually. The new installation figure continued to rise until 2010, at 57 MW_{th}, 62 MW_{th} and 74 MW_{th} in 2008, 2009 and 2010 respectively. The high installation in 2010 was due to the introduction of RHPP and the RHI. However, the total capacity for new STS installation in 2011 experienced a drop (approximately 64.2 W_{th}), due to the uncertainty of the RHI scheme for the domestic sector. Nevertheless, the report indicates that as of 2011, the new installed capacity of STSs in the UK amounted to 3% of the total newly installed capacity in Europe, of which 80% of that value was contributed by flat plate collectors [55]. Fig. 8 shows the annual new installation as well as the cumulative installation capacity for STS in the UK from 2001 to 2011.

A recent report published for DECC by AEA Technology Plc in 2010 [56] analyses the renewable energy growth in the UK until 2020. To meet the UK's NREAP target of 15% energy coming from the renewable sources, three projection scenarios have been identified: low, central and upper projection. According to the report, the RHI will provide a steady increase in terms of installation growth of the STS until 2020, particularly in the domestic sector [56]. This projection is based on the proposed RHI return on investment of 6% per annum [40] and an annual STS installation growth of 5%, 10% and 15%. Fig. 9 shows the projection of annual output (in GWh) from 2010 until 2020 for each scenario. By 2020, the STS could produce 1505 GWh, 2510 GWh and 4094 GWh under the low, central and upper projection scenarios respectively [56].

5. Financial analysis

Based on the RHI scheme, it is possible to quantify the return that could be gained by installing an STS in a building. The financial analysis evaluates the impact on consumers in the following areas; the total profit gain, the average annual return on investment and the payback period. The UK government estimates that the return on investment for installing an STS under the RHI incentive to be around 6% per annum [40]. The financial analysis is conducted on both non-domestic and domestic buildings, using different values of solar insolation. It is

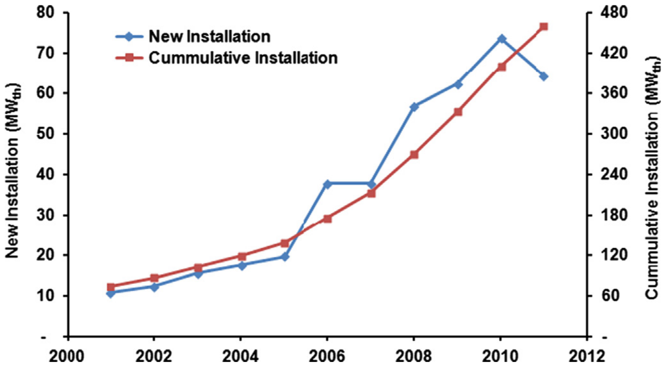


Fig. 8. Annual new installation and cumulative installation capacity for STS in the UK (2001–2011). Adapted from [55].

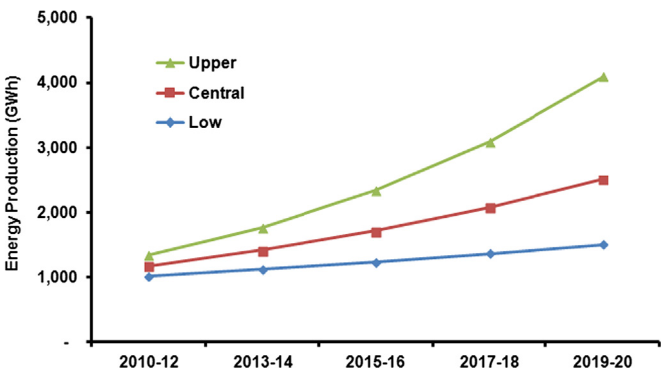


Fig. 9. Projection of energy production from STS installation (2010–2020). Adapted from [56].

Table 5
Nomenclature for the financial analysis.

Item	Symbol	Amount	Unit
Annual maintenance cost	M		£
Annual RHI income	R_{RHI}		£
Annual revenue	R_A		£
Annual saving from onsite usage	R_{SAV}		£
Annual solar insolation	S_T	800–1300	kWh/m^2
Annual solar thermal output	Q_S		kWh
Average annual return on investment	ROI		£
Contract duration	T	20	year
Installation cost	C		£
Payback Period	PP		year
Overall collector's efficiency	E_c		
Positioning factor[a] [57]	K_P	0.95	
RHI rate	r		£
Solar collector area	A		m^2
Total profit	P_T		£
Total revenue	R_T		£
Utility rate (gas or electric)	u		£

[a] Positioning factor provides the percentage of maximum yearly insolation output for various orientation and tilt [57]. In the UK, a south facing solar collector mounted at a 35° pitch will yield between 95% and 100% of the maximum insolation output. In this paper, the minimum value of positioning factor is chosen, i.e. 95%.

assumed that an AES flat plate collector is used in all installations, and the collectors are placed at the optimum position—mounted on a south facing rooftop on a 35° pitch from horizontal [57]. The nomenclature needed for the financial analysis is presented in Table 5. Based on these nomenclatures, the relationships between the financial parameters are given in Eqs. (1)–(8).[3]

$$Q_S = E_c \times K_P \times S_T \times A \times 0.46 \quad (1)$$

$$R_{RHI} = Q_S \times r \quad (2)$$

$$R_{SAV} = Q_S \times u \quad (3)$$

$$R_A = R_{RHI} + R_{SAV} - M \quad (4)$$

$$R_T = R_A \times T \quad (5)$$

$$P_T = R_T - C \quad (6)$$

$$PP = C/R_A \quad (7)$$

$$ROI = (P_T/C)/T \quad (8)$$

To further streamline the calculations, the following assumptions have been made: (i) the installation cost is paid in full at the beginning of the project—no loan is taken to fund it; (ii) the overall efficiency of the collector degrades by 0.5% annually [58]; (iii) the annual maintenance cost is £64 [59]; (iv) the calculation is done for the duration of contract period, i.e. 20 years with a rate of 8.9 p per kWh for non-domestic installation and 17.3 p per kWh for domestic installation. In each location, two cases are analysed: (i) the utility bill savings when replacing gas heating, and (ii) the utility bill savings when replacing electric immersion heating. According to the EST, the average gas price is £0.049/kWh and the average electricity price (standard rate) is £0.1439/kWh [61]. Taking into account the effect of inflation rate, it is calculated that the average RPI for the past 10 years in the UK is 3% [46], which affects the RHI rate and the annual maintenance cost. Also, it is assumed that the annual utility cost increases by 8% per year [46]. Because of the changes in the RHI rate, maintenance cost and the utility cost per year, this causes the annual revenue to change accordingly. Therefore, an exception is made to the calculation of the payback period—this is determined by the number of years before the system begins to generate any profit [46].

5.1. Non-domestic installation

For the non-domestic installation, three sizes of solar collector are investigated; 10 m^2, 20 m^2 and 30 m^2. Figs. 10–12 show the results from the financial analysis for solar collectors of sizes 10 m^2, 20 m^2 and 30 m^2 respectively. The installation cost for each installation (in increasing order of the solar collector's size) is approximately £7500, £14,000 and £20,000 [59]. In all cases, the applicant could generate a total generation income from the RHI incentive of between £6000 and £30,000. In terms of savings on utility bills, total saving from onsite usage amounting from £6000 to £33,000 and from £21,000 to £106,000 for Cases (i) and (ii) respectively have been calculated. From an investment point of view, all installations are feasible as each one generates a positive return. All installations could generate a total profit of between £3000 and £114,000 in the 20 years period, with an average annual return of investment ranging from 2.4% to 28.4%. The installation cost could be recovered in between 4 and 14 years, depending on location. It is observed that an STS that replaces electric immersion heating generates a higher return than the one that replaces gas heating, owing to the fact that the average cost of electricity is three times the cost of gas heating.

However, for the non-domestic sector, any income generated from the RHI scheme is taxable depending on the situation [62]. If the system is owned by a sole trader, a partnership or a limited

[3] According to the AES Ltd.'s Technical Report [60], the measured efficiency of AES's flat plate collector is 0.46 (see Eq. (1)).

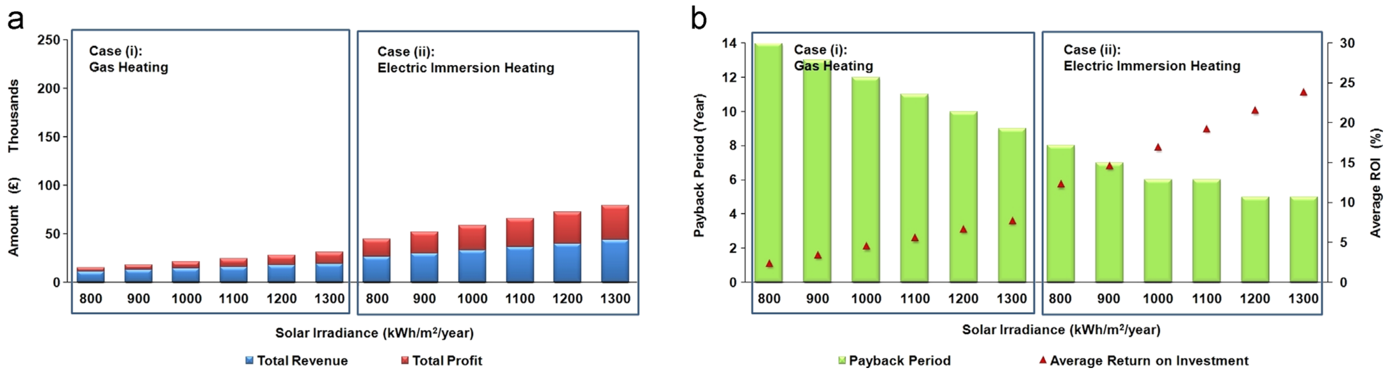


Fig. 10. Financial analysis of installing an STS with a collector size of 10 m^2, where (a) indicates the total revenue and the total profit gained in 20 years, and (b) shows the payback period and the average annual return on investment.

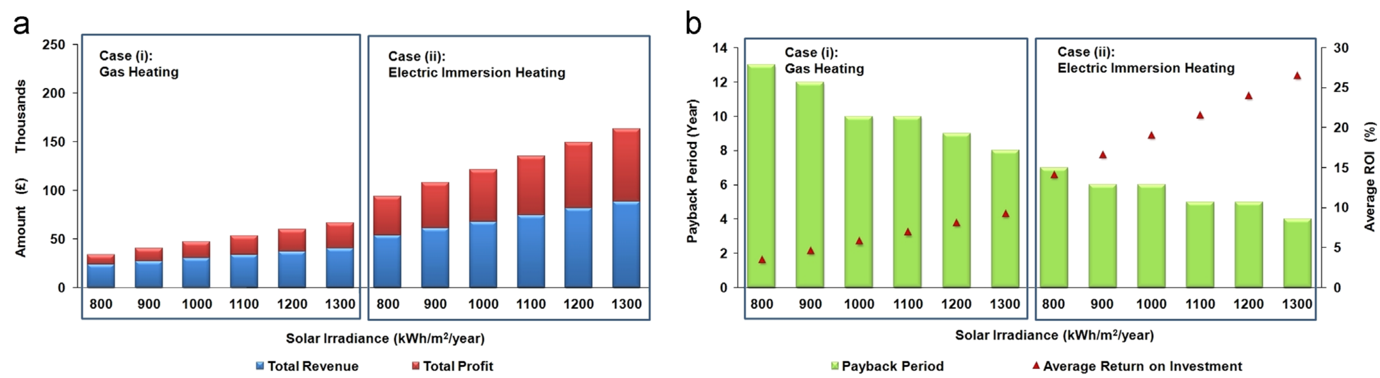


Fig. 11. Financial analysis of installing an STS with a collector size of 20 m^2, where (a) indicates the total revenue and the total profit gained in 20 years, and (b) shows the payback period and the average annual return on investment.

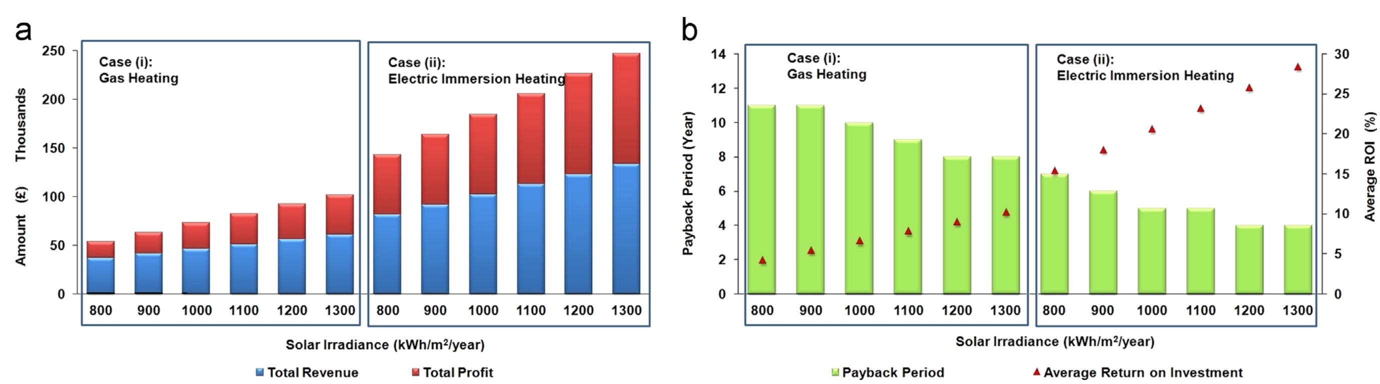


Fig. 12. Financial analysis of installing an STS with a collector size of 30 m^2, where (a) indicates the total revenue and the total profit gained in 20 years, and (b) shows the payback period and the average annual return on investment.

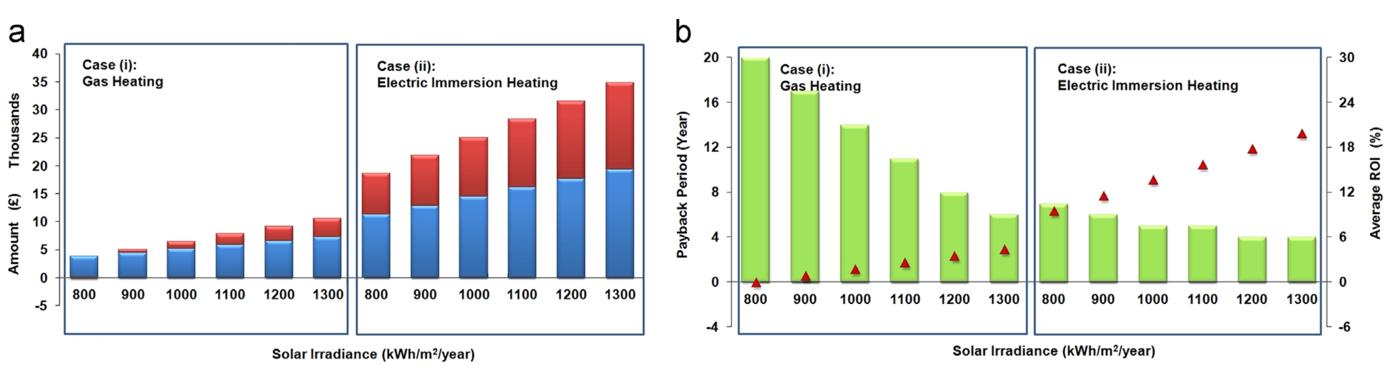


Fig. 13. Financial analysis of installing an STS with a collector size of 5 m^2, where (a) indicates the total revenue and the total profit gained in 20 years, and (b) shows the payback period and the average annual return on investment.

liability partnership (LLP), the tax will be at their marginal rate (from 20% to 50%). For a company, the RHI income is subjected to the corporation tax.

5.2. Domestic installation

For the domestic installation analysis, the typical size of solar collector is used, i.e. 5 m^2, and the installation cost of this system is estimated to be £3900 [59]. The result obtained from the financial analysis is presented in Fig. 13. It is found that an installation of an STS in a location that receives 800 kWh/m^2 and using a gas heating boiler is not advisable since it generates a negative cash flow. As for other installations, any household could generate a total generation income from the RHI incentive of between £2400 and about £3500. In terms of savings on utility bills, total saving from onsite usage amounting from £3700 to £5500 and from £12,200 to £17,600 for Case (i) and (ii) respectively have been calculated. All feasible installations could generate a total profit ranging from £500 to £15,500 depending on the locations, with an average annual ROI of between 0.8% and 19.8%. The installation cost could be recovered in between 4 and 17 years, depending on location. Similarly to the previous analysis, an STS that replaces electric immersion heating generates more return.

Interestingly, the domestic sector which received the RHPP scheme is also eligible for the RHI scheme. If the RHPP scheme is included into the calculation, the household could benefit from an additional advantage, and the analysis is presented in Fig. 14. Any applicant who received the RHPP voucher scheme gains an extra profit of £300 for each case, due to the reduction in initial cost of installation. All the installations produce positive cash flows and generate slightly higher annual returns on investment (from 0.3% to 21.9%). The income generated from this scheme is not taxable.

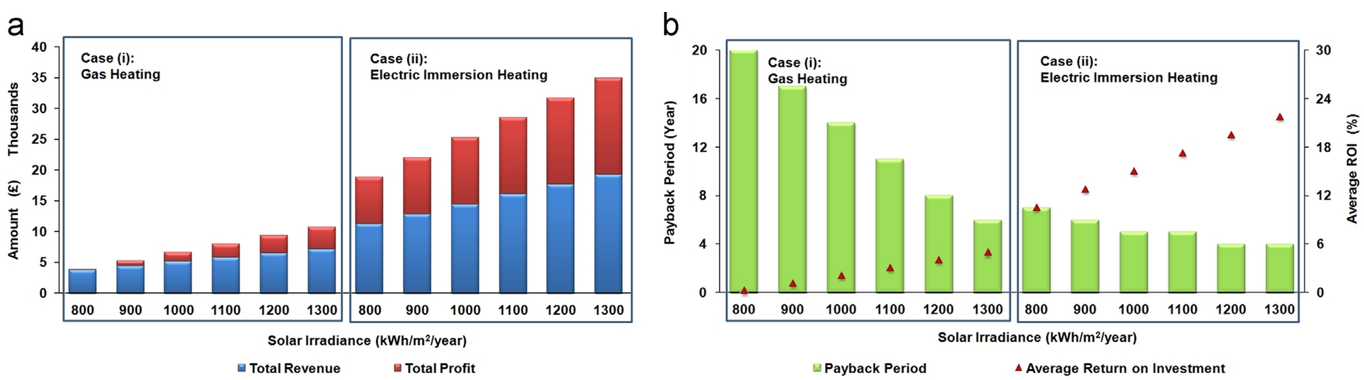


Fig. 14. Financial analysis of installing an STS with a collector size of 5 m^2, where (a) indicates the total revenue and the total profit gained in 20 years, and (b) shows the payback period and the average annual return on investment. The analysis assumes that the applicant received the RHPP voucher scheme worth £300.

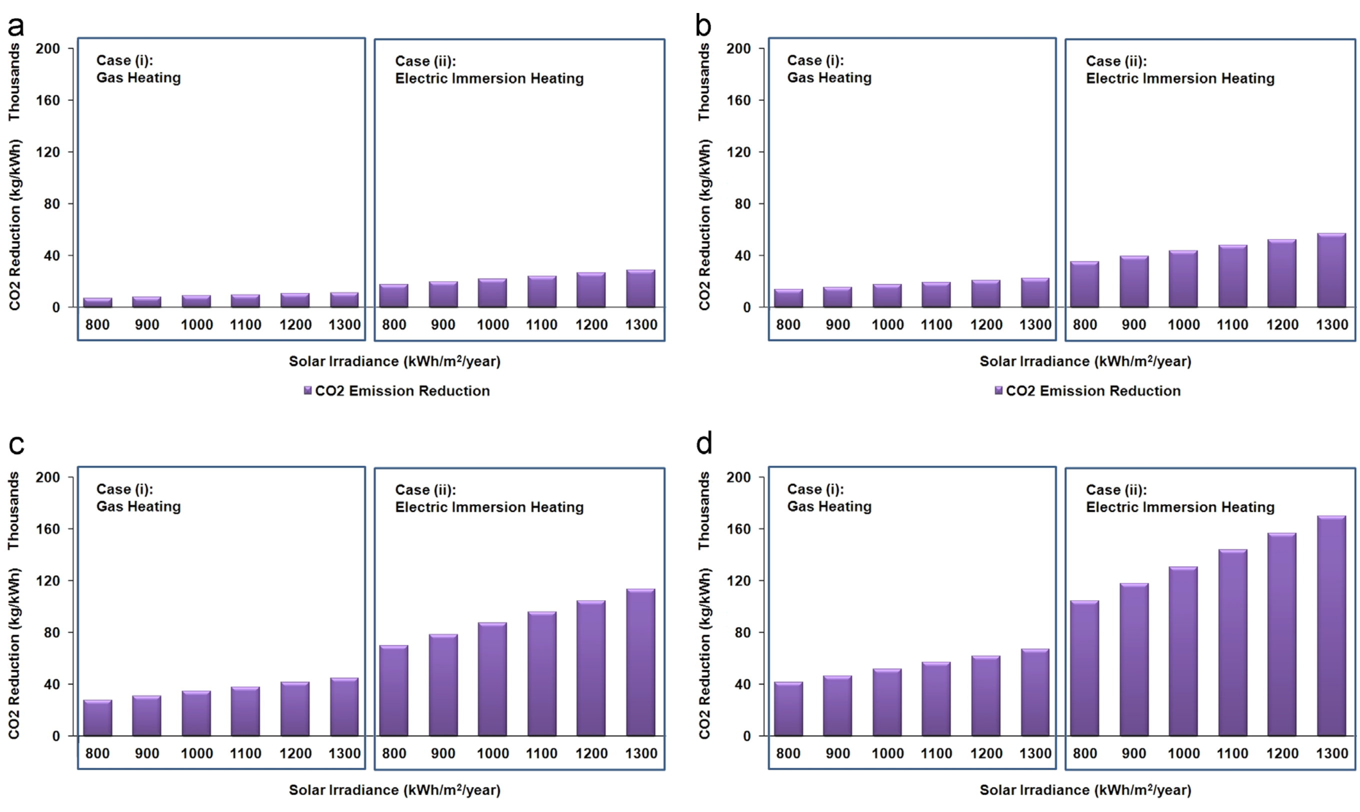


Fig. 15. Reduction in carbon dioxide emission for installing a STS in 20 years for solar collector area of: (a) 5 m^2; (b) 10 m^2; (c) 20 m^2 and (d) 30 m^2.

Presently the RHI scheme for domestic consumer is still under consultation [39], and is expected to begin in summer 2013. The consultation proposed a rate of 17.3 p per kWh for a period of 7 years for a heat payment of 20 years. In the consultation paper, the government acknowledges the importance of providing a financial help towards the capital cost. One of the proposals is to ensure that the RHI scheme will work alongside the Green Deal to facilitate the uptake of STSs.

6. Reduction in CO_2 emission

It is also possible to deduce the reduction of carbon dioxide (CO_2) achieved by installing a solar thermal system on a building. For gas, the CO_2 emissions factor is 0.206 kg/kWh while for electricity, the factor is 0.523 kg/kWh [63]. This section presents the CO_2 emission reductions for STSs installed in both domestic and non-domestic buildings discussed in Section 5. Fig. 15(a)–(d) show the CO_2 emission reductions from installing a STS in a building using a flat plate collector of size 5 m^2 to 30 m^2 respectively over the 20 years period. For the whole contract period, the CO_2 emission could be reduced by between 6900 kg and 28,300 kg for an installation using a 5 m^2 solar collector and between 41,200 kg and 169,800 kg for an installation using a 30 m^2 solar collector—depending on the location of installation. Significant reductions are observed when substituting the electricity immersion heating, due to a larger CO_2 emission factor. A larger collector area will result in more solar thermal output; hence more CO_2 emission could be reduced.

7. Conclusions

Solar energy has significant potential in the UK. The installation of renewable heat technologies has grown considerably in this country—including STSs. This is mainly due to the introduction of various policies, regulation and programmes by the government, as well as strong supports from the R&D sectors. The recent introduction of the RHI scheme will definitely become the key driver to boost the solar thermal industry in the country. Based on a number of assumptions, it is calculated that the RHI rate in the UK generates reasonable revenue and profits to both domestic and non-domestic installations.

It is possible to conclude that the RHI incentive could be considered as a lucrative investment due to the high return particularly for installations in the southern part of the country, which receives a higher solar insolation per annum. With an average annual return on investment of as high as 28%, the applicants are better off installing an STS than putting their money in a bank savings account (typical savings accounts have an average return of 0.53% per annum in the last 2 years [64]). It is also observed that the savings from electric immersion heating generates a higher return as compared to savings by gas heating.

The cost of an STS also plays a crucial role as lower costs could generate more revenues and could attract more people to invest in STS installations, especially in domestic sector. A recent report indicates that the household sector is one of the key groups that will ensure the successful renewable heat penetration in the UK [56]. Phase 2 of the RHI scheme targeted the domestic consumers, by offering a good RHI tariff as well as incorporating the Green Deal to help finance the initial cost of installation. If the government is serious about the renewable heat penetration, a higher rate of RHI could be offered, e.g. between 32 p and 34 p per kWh, and a longer payment period, e.g. between 17 and 20 years, which would translate in higher returns on investment. This would attract more investors in this sector. It can also be seen in Section 5 that any installation in the northern region gains significantly lower returns than those in the southern part of the UK—potentially discouraging investors. A way to address this issue would be to provide a higher RHPP voucher scheme for financing these installations, which would push more uptakes. However, this depends on whether the government has enough budget capability to support these proposals or not.

The installation of STSs can contribute to reduce the emission of CO_2 to the environment. It could reduce the emission of CO_2 by as much as 169,800 kg.

Although the solar thermal industry has shown significant growth in terms of number of installations, it is essential that the government increases awareness on the renewable heat technology, specifically on the financial incentives and benefits of installing the STS. With this, a successful renewable heat technology penetration in the UK is very likely.

Acknowledgement

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